

# Truckee Canal Failure on 5 January 2008

## Investigative Evaluation Report

March 2008

Contract 06CS204097A



*Prepared for:*

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Bureau of Reclamation  
Mid-Pacific Region  
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# 1. INTRODUCTION

This report presents the results of an investigative evaluation of the failure of the Truckee Canal that occurred in the early morning hours of 5 January 2008. The report is based on information gathered by the URS Investigative Evaluation Team (Team) during a field visit to Fernley, Nevada, from 13 through 15 January 2008 and review of documents received subsequent to that visit. During the field trip, the Team carried out the following activities:

- Inspected the Truckee Canal at and in the vicinity of the failed levee.
- Conducted interviews with personnel from the Truckee-Carson Irrigation District (TCID) and U.S. Bureau of Reclamation (Reclamation) who had knowledge of the failure event and/or events and activities during the time period leading up to and following the failure.
- Completed a brief reconnaissance of other sections of the Truckee Canal in the Fernley vicinity.
- Reviewed documents and photographs made available by TCID and Reclamation

Following the field visit, additional information was made available by Reclamation.

The report references the authorization for the evaluation; summarizes the Team's professional experience; presents a brief history of the Truckee Canal and the events leading up to the failure; states the evaluation objectives; describes the investigation; outlines potential factors contributing to the failure; and presents the Team's findings resulting from the investigation.

Notes from interviews, list of documents reviewed, and selected pertinent photographs are included as appendices to this report.

# 2. AUTHORIZATION

The investigative evaluation was authorized by Reclamation's Order No. 06A4204097A dated 11 January 2008 under Contract No. 06CS204097A.

### **3. INVESTIGATIVE EVALUATION TEAM**

The following specialists comprise the Investigative Evaluation Team:

**John W. France, PE**  
**URS, Vice President, National Dams Technology Leader**

Mr. France has over 32 years of experience in engineering consulting and design. The majority of Mr. France's technical work for the past 24 years has focused on dams and water retention and delivery structures. This experience includes dam safety inspections and analyses, detailed geotechnical and geological field and laboratory investigations, hazard classification, seepage and static stability analyses and evaluations, seismic stability/seismic deformation analyses, conceptual and final designs of new structures, rehabilitation of existing structures, and consultation during construction. Mr. France is a nationally recognized expert in dam engineering and dam safety

**Bill Moler**  
**URS, Principal Geologist**

Mr. Moler has over 35 years of experience in engineering geology, and project/construction management for the planning, investigation, design and construction of water resource development projects such as dams, levees, canals, pipelines, and power plants. Over the years Mr. Moler has served on a number of engineering panels of experts for dam projects around the world. Currently Mr. Moler is the leader of the Geotechnical Services Group at URS's Sacramento Office where he is Quality Assurance Officer for the California Department of Water Resource's Levee Geotechnical Evaluation project.

### **4. BACKGROUND**

#### **4.1 General**

The Truckee Canal was constructed by Reclamation between 1903 and 1906 as part of the Newlands Project. The canal serves two purposes: (1) diversion of water from the Truckee River at Derby Dam to the Carson River at Lahontan Reservoir and (2) delivery of water to users at various locations along the canal. Currently the canal is operated and maintained by TCID.

In the vicinity of Fernley, the canal was constructed by excavating a ditch with a bottom width of about 16 feet and with internal slopes of about 1.5 horizontal to 1 vertical (1.5H:1V). Excavated soil was placed adjacent to the ditch on either side, creating embankments to contain canal flows. Original drawings

indicate that the embankment on the downhill side (the side between the canal and the City of Fernley) had a crest width of about 8 feet and the canal was about 15 feet deep, thereby resulting in a canal width of about 61 feet at the top of the embankment (see Figure 1). Over the years, sand and brush that had accumulated in the canal has been removed and placed on the canal's landside embankment as a waste berm. Grading and placing road-base material on the embankment crest has resulted in widening of the crest and steepening of the upper waterside embankment slope above the maximum water surface level in the canal. The present canal embankment crest width is about 20 feet.

According to the original design drawings, canal flow capacity is reported to be about 1,200 cubic feet per second (cfs) at a velocity of 2.86 feet per second (fps) with about 2 feet of freeboard relative to the canal embankment crest.

The canal is operated by controlling diversions from the Truckee River at Derby Dam and through a number of hydraulic structures along the length of the canal. Several waste ways or spillways and several check structures are located along the canal to control flow. The canal is normally operated to divert flow from the Truckee River to Lahontan Dam during the fall, winter, and spring. During summer, the canal is maintained full ("checked up") in order to provide water deliveries to TCID water users.

## **4.2 5 January 2008 Failure**

Early in the morning of 5 January 2008, at about 4:00 a.m., a breach failure of the downhill embankment of the canal occurred at about Station (Sta.) 714+00, in the City of Fernley, Lyon County, Nevada. The canal drained through this breach from both the upstream and downstream directions. TCID personnel responded to the breach by opening an upstream wasteway (Gilpin), shutting off the diversion at Derby Dam, and plugging the breach itself. However, several hundred homes in Fernley were flooded before flow through the breach could be stopped. Reportedly, water flowed through the breach for up to 9 hours and water depths of up to 8 feet accumulated in some locations, with water depths of 1 to 4 feet common throughout a large housing development in Fernley.

Prior to 4 January 2008, TCID had been diverting water through the canal at an approximate average daily rate of 370 cfs. According to Reclamation analyses, a storm event with 1.91 inches of precipitation in the Reno/Sparks area on 4 January 2008 resulted in significant increases in both Truckee River flows and diversions through the Truckee Canal. Reclamation estimates of canal flows, as measured at the Wadsworth gage located in the canal about 4 miles upstream of the breach site, are presented in Table 1.

**Table 1. Canal Flows 4 – 5 January 2008**

TIME	FLOW
12:00 AM through 10:00 AM, 4 January 2008:	374 cfs (average)
5:00 PM, 4 January 2008:	400 cfs (+/- 15 cfs)
8:15 PM, 4 January 2008:	>500 cfs
9:15 PM, 4 January 2008:	>600 cfs
~12:00 AM, 5 January 2008:	~700 cfs
12:00 AM through 4:30 AM, 5 January 2008:	Between 700 and 750 cfs
4:30 AM, 5 January 2008:	Peaked at 751 cfs
1:15 PM, 5 January 2008:	0 cfs

cfs = cubic feet per second

Reclamation further estimates that flows at the failure site would have been similar to those at the Wadsworth gage, but the flows at the failure site would have occurred 2 hours and 15 minutes (+/- 30 minutes) later than those at the gage, because of the time required for water to flow the 4 miles between the gage and the failure site. Analysis by Reclamation indicates that local runoff that flowed into the canal between the Wadsworth gage and the failure site prior to and at the time of the breach would have been negligible, so flows at the failure site would not likely have been significantly greater than those at the Wadsworth gage. Data from the Hazen gage, located in the canal about 14 miles downstream of the breach site, appear to have been matching flows at the Wadsworth gage up to the time of the failure, considering the flow time between the two gages.

From its analysis, Reclamation notes that the peak flow rate of 751 cfs at the Wadsworth gage, recorded at the time of the 5 January 2008 breach event, is the fifth highest flow rate recorded when compared with hourly flow data available from February 1995 through September 2006. However, the 751 cfs flow is almost 20 percent less than the highest hourly flow of 921 cfs recorded in April 2002, and the records include three events with hourly flows in excess of 800 cfs during that same period. Reclamation further notes that an evaluation of average daily flow records for the period of October 1966 through December 2007 indicates 28 instances of average daily flows exceeding 650 cfs and 19 instances of average daily flows exceeding 751 cfs. These instances may also represent elevated flow rates over a period of several days or even weeks. However, it should also be noted that the ramping rate (rate of increase in flow) for the hours prior to the 5 January 2008 breach is one of the fastest ramping rates observed by Reclamation in the hourly records available for the period from February 1995 through September 2006.

During the evening hours of 4 January 2008 and into the early morning hours of 5 January 2008, TCID personnel were on site at the canal, adjusting diversion gates at Derby Dam and monitoring flow in the canal. However, none of the TCID activities resulted in personnel passing the site of the breach during the

time leading up to the failure. TCID personnel reported that there was no ice observed in the canal on 4 January 2008.

TCID personnel carried out a partial inspection of the canal during the morning of 4 January 2008. This inspection included specific locations that had previously been identified for regular scrutiny, but did not include traveling the full length of the canal. The 5 January 2008 breach location was not in an area previously identified for scrutiny, and that location was not visited on the morning of 4 January 2008, in part because of safety concerns related to weather conditions and travel along the canal embankment crest.

### **4.3 Historical Truckee Canal Failures**

Eight failures of the Truckee Canal embankment are known to have occurred prior to the 5 January 2008 failure, as follows:

- 18 April 1918
- 10 December 1919
- 2 January 1921
- 13 December 1951
- January 1957 (exact date not known)
- 1959 (month and date not known)
- 1 January 1975
- 12 December 1996

The location of the 18 April 1918 failure is not known, but was reported to have been related to construction of structures. The 2 January 1921 failure was at Sta. 1100+00, near a site of known seepage. The 1975 breach at Sta. 590+00 was reported to have been caused by an ice jam. Available information from the 12 December 1996 breach at Sta. 790+00 suggests that it may have been very similar to the 5 January 2008 breach; however, there are no records of any detailed investigations of that failure so a definitive cause of failure is not known. Information on the details or causes of the other four historical breaches is very limited to nonexistent. The month and date are not known for the 1959 failure, and the specific date in January is not known for the 1957 failure. Reclamation's evaluations indicate that the 1919, 1951, 1975, and 1996 failures each occurred after a period of increased Truckee River flow, which would suggest that they may have been associated with increased canal flows to divert water to Lahontan Reservoir and/or with storm events.

## **5. OBJECTIVE**

The Team objective was to evaluate available information and develop opinions as to potential factors contributing to the failure of the Truckee Canal on 5 January 2008.

## **6. INVESTIGATION**

### **6.1 Field Inspection**

The Team made a brief inspection of the canal breach and exposed foundation on the afternoon of Saturday, 12 January 2008. Inspection results generated recommendations for test pit excavations in the canal embankment and foundation, which were completed the following day.

On Sunday, 13 January 2008 the down-hill side of the canal embankment and foundation exposed by the breach was excavated back to undisturbed material and a detailed visual examination was made. Key points were marked with paint for subsequent survey and light detection and ranging (LIDAR) scanning. Bulk samples were collected of the various exposed soil types for laboratory testing. Observation trenches were excavated in the invert of the canal just upstream and downstream of the breach and at the breach site itself. Another trench was excavated just landside of the canal embankment in the foundation area scoured by the flood flow from the breach. A sand cone density test was performed in the foundation material in the bottom of the latter trench.

A general reconnaissance was made of the entire Truckee Canal in the Fernley area, with stops made at points where seepage was being monitored by TCID. A brief visit was also made to the residential neighborhoods damaged by the flooding.

### **6.2 Interviews**

On Monday, 14 January 2008, interviews were conducted with the individuals listed in Table 2. Notes from those interviews are presented in Appendix A.

**Table 2. Interviews**

NAME	ORGANIZATION	POSITION
W.C. Cecil	TCID	Ditch Rider
John Baker	TCID	Water Master
Brian Bailly	TCID	Water Master
Kelly Cecil	TCID	Hydroplant Supervisor, Lahontan Dam
Walt Winder	TCID	O&M Foreman
Ernie Shanks	TCID	Board of Directors, President
Dave Overvold	TCID	General Manager
Betsy Rieke	Reclamation	Area Manager
Locke Hahne	Reclamation	O&M
Harvey Edwards	Reclamation	O&M
Ken Paar	Reclamation	Deputy Area Manager
Mike McCulla	Reclamation	Geologist
Jeff Rieker	Reclamation	Hydraulic Engineer

## 6.3 Document Review

Reclamation and TCID made a number of reports and photographs available for review during the field visit. Following the field visit the Team requested additional documentary evidence. Reclamation provided five binders of supplemental information. This information was reviewed for preparation of this report. A complete list of these documents is included in Appendix B.

Of special value to the Team were the following reports prepared by Reclamation:

- *Initial Hydrologic Analysis of the Truckee Canal Breach, Newlands Project, Nevada*, February 4, 2008. Prepared by USBR, Mid-Pacific Region, Lahontan Basin Area Office, LO-900.
- *Truckee Canal Breach, Station 714+00, Geologic Investigations, Newlands Project, Lahontan Basin Area Office – Nevada*, January 2008. Prepared by USBR, Mid-Pacific Region, Geology Branch, MP-230.
- *Truckee Canal Breach, Station 714+50, Muskrat Burrow Investigation, Newlands Project, Lahontan Basin Area Office – Nevada*, January 2008. Prepared by USBR, Mid-Pacific Region, Geology Branch, MP-230.

## 7. **FAILURE SITE GEOLOGY AND EMBANKMENT CONFIGURATION**

Near-surface geology at the failure site is characterized by Lahontan Lakebed sediments consisting of well-bedded, laterally extensive, moderately to highly indurated siltstone and claystone, which can be classified as elastic silt (MH) and lean and fat clay (CL and CH). This unit is cut by two prominent sets of vertical joints. The lakebed sediments are underlain by a thick sequence of coarse alluvial fan deposits that dip northward below the canal. The deposits vary rapidly in grain size, laterally and vertically, but are mostly composed of poorly graded gravel with silt, sand and cobbles (GP-GM).

The lakebed sediments form an excellent foundation material for the canal. At normal canal velocities, the beds are largely non-erosive, have a very low hydraulic conductivity, and exhibit good overall stability. However, the hydraulic conductivity of the underlying alluvial fan deposits is very high. Due to their dense nature, liquefaction potential of these fan materials during a seismic event is considered to be extremely low.

LIDAR imagery of the canal in the vicinity of the breach made following the failure, in conjunction with geologic mapping, and trench excavation, suggests that before the breach occurred, this section of the canal had 3 to 5 feet of fine-grained lakebed sediment in the canal invert, overlying and effectively sealing water flow from entering the underlying coarse alluvial fan deposits. During the breach, scour took place in the invert of the canal, eroding through the lakebed sediments and creating a relatively large scour hole into the alluvial fan deposits. This hole subsequently filled in with sand as flow through the breach was reduced.

The canal embankments, which are approximately 8 feet high adjacent to the canal cut in the breach area, are composed of a homogeneous mixture of silt and clay with minor amounts of sand and gravel. Embankment lift lines are not distinct and there are no horizontal layers of pervious material. The landside embankment slope is blanketed with sand and vegetative material derived from years of periodically cleaning out the canal. The bond between the embankment material and the lakebed sediment foundation is excellent. Figure 1 shows a cross section through the breach, with the existing embankment projected in the background.

## **8. POTENTIAL FACTORS CONTRIBUTING TO FAILURE**

The Team considered the following potential factors that could have contributed to the canal failure:

### **8.1 Overtopping**

An increase in water level in the canal due to an increase in diversion flows at Derby Dam caused by high flows in the Truckee River from the storm could have caused the water level in the canal to rise above the embankment crest, resulting in overtopping flow that eroded and breached the canal. Alternatively, overtopping could have resulted from partial blockage of the canal due to floating ice or a partially closed check structure downstream of the breach that, in conjunction with the increased flow, caused the embankment to overtop.

### **8.2 Piping Due to Through- or Under-Seepage**

Internal erosion or piping of the canal embankment and/or foundation could have occurred due to a rapid rise in the canal's water level that increased the phreatic surface and consequently, increased the seepage exit gradient to a point where it would erode the embankment or foundation material. A piping failure could also have resulted from seepage through a geologic or construction defect that reached a critical condition which, in turn, led to internal erosion and failure.

### **8.3 Blowout Due to Foundation Seepage**

Seepage entering the pervious sand and gravel foundation stratum could have build up pressure beneath the overlying relatively impervious lacustrine foundation deposits at the landside toe of the embankment, and could then have ultimately blown out the lacustrine deposits, which would be followed by progressive erosion and breach development.

### **8.4 Piping Due to Rodent Activity**

The increase in water level in the canal may have caused water to enter animal burrows in the embankment, thereby shortening the seepage path and increasing the seepage exit gradient within the embankment, resulting in piping, subsequent erosion and breach of the embankment.

## **8.5 Erosion**

A rapid increase in flow in the canal could have increased flow velocity which, in conjunction with bedload and floating debris, could then have resulted in erosion of the canal embankment and/or scour of the cut portion of the canal. It should be noted that the breach was located just downstream of the outside of a bend in the canal, and the bend is protected with riprap. The erosion could have grown large enough that it eroded entirely through the embankment or removed enough of the embankment that the water pressure in the canal blew out the remaining section of the embankment.

## **8.6 Embankment Instability**

The increase in water level could have resulted in an increased loading condition on the embankment, resulting in instability of the landside embankment slope.

## **8.7 Seismic Activity**

The Truckee Canal is located in the northwest-trending Walker Lane seismic belt, which is capable of generating large earthquakes (surface wave magnitude [Ms] 6.0 to 7.5 maximum credible earthquake [MCE]). A potential mode of failure could have been liquefaction of the embankment or embankment foundation during a strong seismic event.

## **8.8 Sabotage**

The embankment could have been sabotaged prior to or at the time of the increased flows in the canal. Possible means of sabotage include use of explosives to cause a crater in the embankment deep enough to allow water to flow through, or removal of a section of embankment using construction equipment to produce the same ultimate effect.

# **9. FINDINGS**

The Team evaluated the many potential factors that could have contributed to failure as described above in light of the information obtained during the investigations, and has developed these findings. The following four modes are considered *unlikely* causes of failure:

## **9.1 Overtopping**

Overtopping was judged to be extremely unlikely as a factor in the failure, because all of the available information suggests that the water level at the breach location did not rise above elevation 4,193.0 mean sea level (msl), which is 3.5 feet below the canal embankment crest at about elevation 4,196.5. Although gage data suggest that canal flow was relatively high at the time of the failure, flows up to 20 percent higher have been recorded in the past without overtopping. No evidence of erosion of embankment crest was observed in the vicinity of the breach, and the location of the breach has never been reported as a low spot in the embankment crest. Photographic evidence and eyewitness reports indicate that snow was present on the waterside slope of the embankment some distance below the crest elevation immediately after the failure; any snow would have been melted to the crest level had the embankment overtopped.

## **9.2 Blowout Due to Foundation Seepage**

Blowout due to foundation seepage is judged to be extremely unlikely as a factor in the failure, because of the geology at the site and the historical performance at the breach location. The geologic information indicates that prior to the breach there was at least a few feet of low-permeability lakebed deposits in the bottom of the canal, between the canal invert and the underlying pervious fan deposits. These low-permeability deposits would have prevented significant seepage from entering the sand and gravel stratum. In addition, the foundation strata dip toward the downhill (left or north) side of the canal, resulting in a relatively thick cover of lakebed deposits over the sand and gravel stratum at the landside toe of the canal embankment. This configuration would require relatively high pressure in the sand and gravel stratum to create a blowout at the toe. Finally, seepage has never been reported at the toe of the embankment in the breach location and, according to TCID personnel, when the canal is “checked up” for irrigation deliveries, the canal water level is maintained at levels as high or higher than were present at the time of the failure. Blowouts have not occurred in the past under these sustained higher head conditions in the canal.

## **9.3 Erosion**

Because of field observations and the canal configuration at the breach, erosion is judged to be extremely unlikely as a factor in the failure. No significant erosion of the waterside canal embankment slope was observed immediately upstream or downstream of the breach location, and the breach is located in a relatively straight section of the canal alignment. Considering the likely canal flow velocities and the nature of the materials in the canal embankment,

significant erosion would not be expected in this relatively straight stretch of the canal.

## 9.4 Seismic Activity

Seismically induced failure is judged to be practically impossible as a factor in the breach because of the lack of reported seismic activity at the time of the breach and because of the plastic nature of the embankment and foundation soils. These characteristics make them less susceptible to significant strength loss from earthquake shaking.

Of the remaining four potential factors that could have contributed to the failure, it is the Team's opinion that piping due to rodent activity is by far the most likely cause of the breach, although the other three potential factors cannot be completely ruled out. In addition, all four of these potential factors would be exacerbated by rapid ramping (increases) in canal flow.

## 9.5 Piping Due to Rodent Activity

The following factors argue in favor of *piping due to rodent activity* as the leading contributing factor in the failure:

1. TCID personnel report that rodents are highly active in the canal in the breach vicinity. Rodents were also observed in the residual water in the canal during the Team's site visit. Numerous animal burrows in the canal banks were observed in the vicinity of the breach by the Team and others. From the reconnaissance of the canal in the vicinity of Fernley, it was the Team's impression that rodent burrows in the canal banks were more prevalent where the canal embankments were constructed of fine-grained soils, as was the case at the breach site, than where the canal was constructed of soils having a significant gravel content.
2. The previously referenced investigation by Reclamation of the animal borrows located about 250 feet downstream of the breach, in essentially the same embankment configuration as the breach site, revealed an extensive network of animal borrows extending from the waterside slope of the downhill canal embankment to very near the landside slope (see figures and photos in referenced report as well as the photos presented in Appendix C). This network of animal burrows extends toward a feature on the landside slope that Reclamation has described as a "collapse feature." This feature consists of a depression running up and down the slope, with a fan deposit of sand at the toe of the slope. No direct, open connection through the last few feet of embankment soil between the end of the burrows and the landside slope was

identified in the investigation; however, such a connection could have collapsed and closed after water stopped flowing. It cannot be irrefutably concluded however, that the feature on the landslide slope did not result from surface runoff. The Team observed surface runoff rills extending down the landside slope at other locations in the vicinity of the breach, but none was as large as the one at the burrow investigation site and none had large deltas of sand deposits at the toe. In addition, the coincident locations of the large feature on the slope and the substantial network of internal burrows lend credence to this as contributing to the breach.

3. The reason that the failure occurred on 5 January 2008, after the water level in the canal rose due to increased diversion rather than during the previous irrigation season, when a high, sustained water level was present, could be that animal activity in the fall increased the size and extent of the burrows at the breach location. Another possible explanation for this sequence of events is that the animal burrows would have drained when the canal water level was lowered after the irrigation season. When the canal water level was ramped up rapidly from about elevation 4,190 to 4,193 on 4-5 January 2008, water would have surged into the empty animal burrows, perhaps creating pressure bursts in the burrows higher than hydrostatic water pressures. These bursts could have hydraulically fractured through the downstream section of the embankment, opening seepage paths that could be subsequently sustained by the higher water levels in the canal. Potential evidence for hydro-fracturing of the embankment above the elevation of the rodent burrows includes the narrow, vertical, urethane-filled cracks identified during the rodent burrow investigation.

The only condition that the Team could identify that argues against animal burrows being a contributing factor to the failure is that TCID personnel report that water levels in the canal, when it is “checked up” during the irrigation season, are higher than the elevations at the time of the failure, and that these higher water levels are sustained for months. Therefore, why did the piping failure not occur under those higher gradient conditions? As noted above, additional animal burrowing and/or surging flows in the burrows could possibly be answers to this question.

## 9.6 Piping Due to Through-or-Under-Seepage

In the Team’s opinion, the following factors argue against *piping due to through- or under-seepage* being a contributing factor in the failure, and make it significantly less likely as a contributing factor than piping due to rodent activity:

1. The geologic investigations of the embankment and foundation immediately upstream and downstream of the breach did not indicate geologic features or construction characteristics that would be expected to produce preferred seepage pathways leading to development of a piping failure.
2. The canal has experienced higher flows and, according to TCID personnel, higher sustained water levels with the canal “checked up” without any reported evidence of seepage at the toe or on the landside slope of the embankment at the breach location. TCID personnel regularly inspect the canal and other areas of seepage have been identified, so it is reasonable to expect that any significant seepage at this location would have been identified prior to the failure.

However, the following factors prevent this potential contributing factor from being completely ruled out:

1. The actual geologic and construction conditions within the breach cannot be known because this embankment section was washed away during the failure. It is possible that an unknown defect existed.
2. Seepage and piping mechanisms can develop over time, without evidence being noted that the failure mechanism has reached a critical state.

## 9.7 Embankment Instability

In the Team’s opinion, the following factors argue against *embankment instability* being a contributing factor in the failure, and make it significantly less likely as a contributing factor than piping due to rodent activity:

1. The canal has experienced higher flows and, according to TCID personnel, higher water levels when “checked up” without any reported problems with instability.
2. The embankment and foundation conditions for significant distances upstream and downstream of the breach location are essentially the same as those at the breach location, and no evidence of instability was observed in those locations.
3. The embankment at the breach location is relatively low, and the presence of very low-strength material would be required to cause instability. No evidence of very low-strength material was observed in the embankment immediately upstream and downstream of the breach location.

However, the following factors prevent this potential contributing factor from being completely ruled out:

1. Reclamation's analysis has indicated that the ramping rate for the rise in canal level in the hours before the breach was among the fastest on record, so the embankment could have been subjected to an unusually severe undrained loading.
2. The actual materials within the breach were washed away during the failure, so very weak material that might have been present could have been washed away during the failure.

## 9.8 Sabotage

With respect to sabotage as a contributing factor in the failure, it was reported to the Team during the interviews that there was some concern regarding the possibility of sabotage. The Team has no firsthand knowledge of these matters and their variability is a matter of law enforcement resolution. It is the Team's understanding that this concern has been conveyed to appropriate individuals with Reclamation's Lahontan Basin Area Office. Pending resolution of appropriate law enforcement investigations, this possible cause of the breach cannot be completely ruled out

# 10. CONCLUSIONS

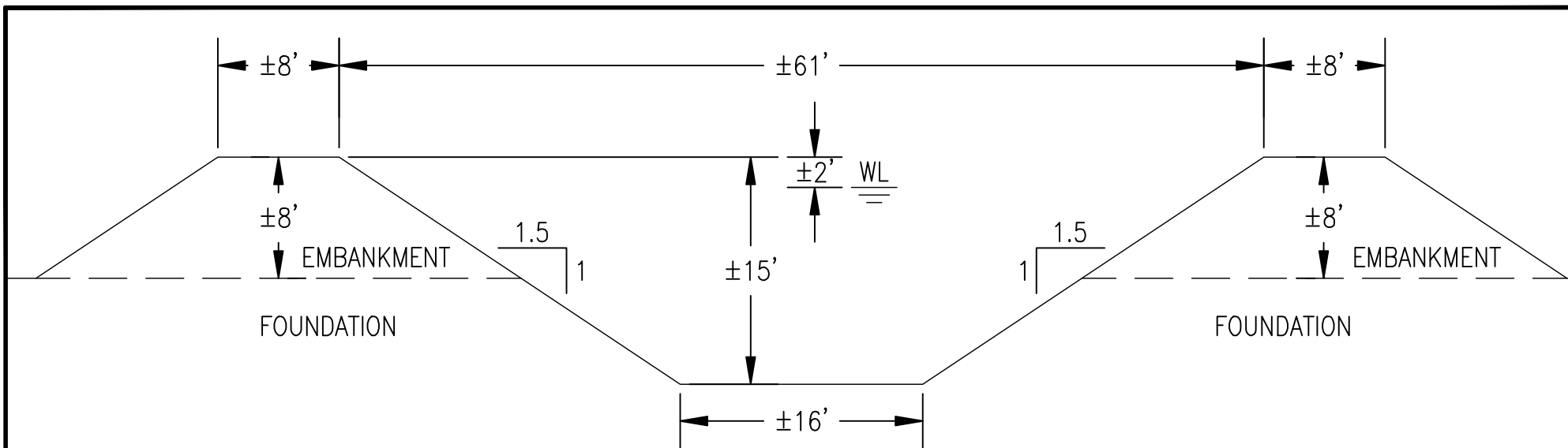
Based on the information available, it is the Team's opinion that *pipng due to rodent activity* is the most likely cause of the 5 January 2008 breach of the Truckee Canal. Certain other possible potential contributing factors that are believed to be much less likely, but cannot be completely ruled out: *pipng due to through- or under-seepage, embankment instability, and sabotage*. Four other potential contributing factors that were considered by the Team, but are judged to be extremely unlikely or practically impossible: *overtopping, blowout due to foundation seepage, erosion, and seismically-induced failure*.

As is typically the case in embankment failures, almost all of the direct evidence of the Truckee Canal failure was removed during the course of the failure. This makes it impossible to reach an absolutely definitive conclusion concerning the cause of failure and, as noted above, in this case prevents the complete elimination of some potential contributing factors.

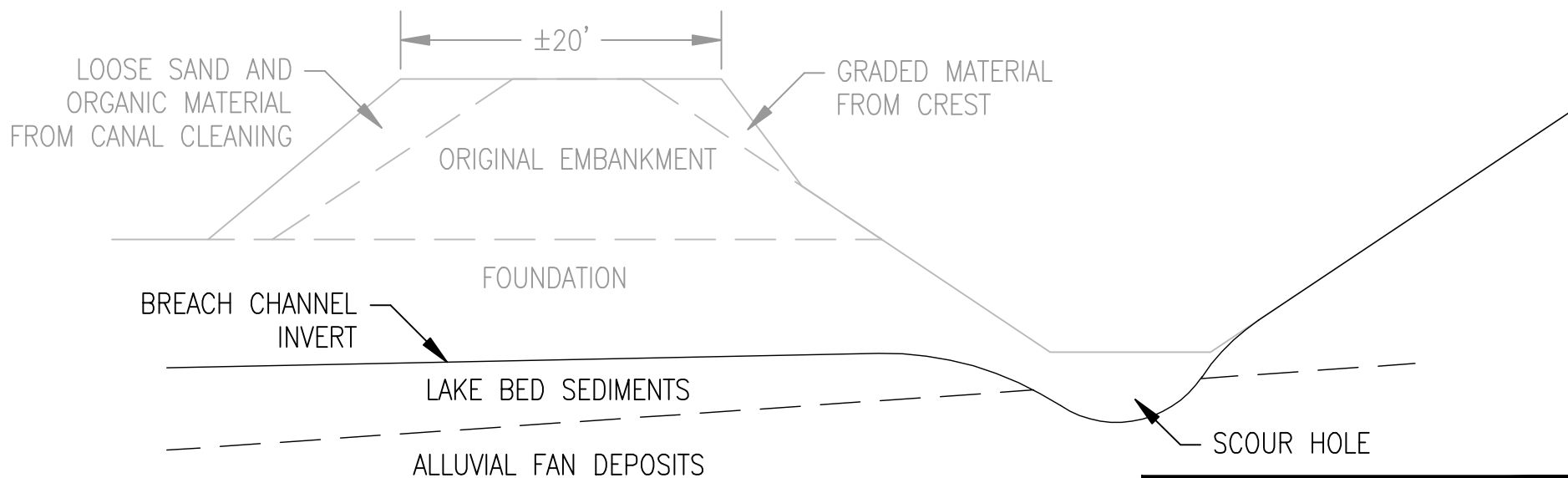
# 11. LIMITATIONS

This report represents the results of URS's investigation evaluation of the Truckee Canal failure that occurred on 5 January 2008. Professional services were provided to evaluate the failure based on a field inspection, interviews, and review of information provided by Reclamation and TCID. The conclusions and

professional opinions presented herein were developed by URS for Reclamation in accordance with generally accepted engineering principles and practices. URS makes no other warranty, either expressed or implied.



ORIGINAL CANAL CROSS SECTION



CROSS SECTION THROUGH BREACH

**FIGURE 1  
TRUCKEE CANAL BREACH**

**TRUCKEE CANAL FAILURE ON  
5 JANUARY 2008  
INVESTIGATIVE EVALUATION REPORT**

**APPENDIX A – INTERVIEWS**

## **TRUCKEE CANAL FAILURE ON 5 JANUARY 2008 INVESTIGATIVE EVALUATION REPORT**

### **APPENDIX A – INTERVIEWS**

Following are notes of interviews with Truckee – Carson Irrigation District (TCID) and U.S. Bureau of Reclamation (Reclamation) personnel conducted on 14 January 2008.

#### **W.C. Cecil – TCID Ditch Rider (12 years with TCID)**

Mr. Cecil's remembrance of the chronology of events on the morning of 5 January is as follows:

- |               |   |
|---------------|---|
| 4:30 AM       | Received call from Brian Baily (TCID Water Master) telling him sheriffs office notified him of problem. He drove to Cook Way near his home where he met sheriff and fire department who were already on the scene.  |
| 4:40 – 5:00AM | Drove downstream along Cottonwood Drive until reaching breach. Approached breach from upstream on north side of levee. Had been raining for two days. Started snowing that night. Snowing at the time of the breach. Snow stopping in the morning about 5:30AM. Breach was about 15-ft wide. Water level in canal had only dropped about 8-in from normal water level before breach. Normal level coincides with the brush growing in the canal.                      |
| 5:05AM        | Called Kelly Cecil (brother and supervisor) to tell him to open Gilpin gate. Called Brian Baily, Dave Overvold, Walt Wender. It takes about 3 hours to open gate by hand but only about 15 minutes with automated actuator.   |
| 5:30AM        | Met Fire Chief Hunley at school. Water running down Farm District Road. Chief Hunley asked about closing gate at Fernley check structure, Mr. Cecil explained the danger of overtopping the canal upstream of Fernley check.  |
| 6:00-6:30AM   | Walt Wender arrived and was shown breach. Walt took pictures. Toured school and flooded area then went back to Community Center to meet Chief Hunley.   |
| 6:30-7:00AM   | Met Brian Baily and went to Fernley check located just upstream of breach to lower gates. Three gates closed by hand took about 1 hour. He was confident water level had dropped and that overtopping would not occur. He understood that John Baker had closed gates to canal at Derby Dam. When he returned to the breach with Walt Wender the breach was larger and the water level in the canal had dropped. He said breach appeared the same as the 1996 breach. |

Mr. Cecil suffered a heart attack a few weeks before and was feeling shortness of breath so he went home to rest.

Mr. Cecil reported eight beavers had been observed between upstream tunnels and Farm District Road east of Fernley. He also reported muskrat activity. He said burrowing animals are more active in the fall than spring.

**John Baker – TCID Water Master (31 years with TCID, 2 years as Water Master)**

Mr. Baker is headquartered in Fallon, about a 30 minute drive from Fernley.

TCID began preparation for the storm 2 days before based on long range forecasts. Verified all check structures along the canal were fully open. He monitored gauges in the Truckee River drainage from the USGS site on the internet.

Mr. Baker's chronology of events on 4 – 5 January is as follows:

8:00PM	Met Brian Baily at Derby Dam and started lowering flap gate to the Truckee River, closing gates to the Truckee Canal, and opening gates at Gilpin Wasteway. Gauge TC-1 at Wadsworth read about 2.0 which is equivalent to about 650 cfs which was up from the 350 cfs that had been routinely diverted in the canal.
about 12PM	Inspected Fernley Check and all other check structures and verified water below bottom of raised gates and all boards removed and free flow condition at about 650 cfs. Inspected Truckee Canal at Wadsworth. Felt adjustments made were adequate to prevent overtopping.
2:00AM	Went home to Fallon
5:00AM	Received call from Brian Baily notifying him of canal breach. Drove to Fernley.
6:00AM	Arrived in Fernley at Painted Rock exit. Verified gates were open at Gilpin wasteway.
6:45AM	Arrived at Derby Dam. Dropped flap gates, then closed gates to canal which took about 15-min with electric actuator. There are eight (8) gates. Difficulty closing two (2) of the gates. One because of debris and another because of mechanical problems remained open but all water in canal spilling at Gilpin wasteway.

Prior to the event 50 cfs was being released to the Truckee River at Derby Dam which is regulated by flap gates. Everything else was being diverted into canal with all gates open. Takes about 3-min to open/close flap gates.

Mr. Baker does not usually focus on the reach of the canal where the breach occurred but he never noted anything unusual. No unusual spike in river gage upstream.

Rained most of the day on the 4<sup>th</sup> and changed to snow sometime after midnight. No ice in the canal.

**Brian Baily – TCID Water Master (20 years with TCID, 2 years as Water Master)**

Mr. Baily's chronology of events on January 4<sup>th</sup> and 5<sup>th</sup> is as follows:

- 3:30PM Hydrological data on USGS website showed Truckee River flows peaking about 24 hours earlier than predicted.
- 4:00PM Drove from Fallon to Derby Dam with Matt \_\_\_\_ (Ditch Rider). Staff gage was reading 0.1. Dropped flood gage 1-ft, and turned on automatic operator and set flap gate to open when water level behind Derby Dam (Truckee Canal) reached 6.5.
- 5:00PM Took Matt \_\_\_\_ home.
- 7:15PM Returned to TCID headquarters in Fallon to monitor instruments. Gage upstream of Derby Dam reading 9.71 indicating problem with automatic gate operator. Canal headworks gage reading 5.69 equivalent to about 721 cfs. Called John Baker to go to Derby.
- 8:17PM Arrived Derby. Weather bad. Rain/sleet/snow. Checked water meter gage which read 721 cfs. Received call from Dave Overvold who had opened Gilpin gate remotely about 60 cfs then 100cfs. Lowered big flap gate manually because automatic operator was not working. Took about 3 minutes. Rotek manufacturer of the operator had been called previously by Reclamation to check out the gate.
- 9:40PM Steve \_\_\_\_ measured 1,700 cfs in Truckee River downstream of Derby. Verified adjustments to gates. Stayed at Derby and took following readings on staff gages in pond upstream of Derby and Truckee Canal headworks:
- | <u>TIME</u> | <u>POND</u> | <u>CANAL</u> | <u>FLOW</u> |
|-------------|-------------|--------------|-------------|
| 8:45PM      | 10.46       | 6.23         |             |
| 9:30PM      | 10.38       | 6.25         |             |
| 10:00PM     | 10.37       | 6.26         | 802 cfs     |
- 10:20 Talked to Dave Overvold. Went to Gilpin to verify gate open to release about 100cfs.
- about 11PM Arrived Gilpin and verified gates open. Snowing hard couldn't read gage. Dangerous road conditions. Drove back to Painted Rock and then to TC-1.

Investigative Evaluation Report  
Truckee Canal

12:30 – 1AM TC-1 read 2.0 and was steady. Point of concern because of high water levels observed in this reach of canal.

1:15AM Drove to Fernley Check. Good shape. Water at bottom of open gates. Maximum flow recorded at Wadsworth 678 cfs.

2:30AM Returned to Fallon via Allendale and other checks. Planned to return at 5AM.

3:15AM Received call from Dave Overvold to discuss situation. Suggested W.C. Cecil look at canal. Would pick him up at 5AM.

4:26AM Received message on mobile phone from Sherriff's Department dispatcher notifying of breach but didn't hear.

4:45AM Heard beeper and read message. From street names in message knew where flooding was occurring but did not know about breach.

about 5AM Called W.C. Cecil. Thought culverts and drains were plugged with debris, not canal breach.

5:15AM W.C. called back and verified levee breach. Kelly Cecil called mixed up code/password to open Gilpin. Kelly called Dave Overvold to give password to Kelly. W.C. called back.

5:20AM Kelly called back to say gates were open.

5:27AM Talked to Walt Winder who was in TCID office in Fallon. Got reading that pond was at 9.56 and canal 5.88 or about 700 cfs. Drove to Fernley in light snow, bad visibility, slick road conditions.

5:45AM Talked to W.C.

6:24AM Talked to John.

6:35AM Talked to Walt

6:45AM Picked up W.C. and went to Fernley Check to lower gates. Manual gates, slow.

7:20AM Gene Mawe from shop arrived to help crank operator.

7:45AM Finished closing gates but flashboards around end still out.

8:30AM Went to Gilpin to open manual gates outside of automatic gates. Kelly already there. John at Derby. About 80 cfs still flowing into canal through inoperable gate.

9:45AM Still about 15 – 20 cfs in canal downstream of Gilpin. Opened manual gates completely.

Could see breach from Cottonwood Drive but didn't go there because he thought breach was at Ricci Road where there had been a seepage problem. Never any seepage observed at breach location. Main concern was overtopping at ditch house at TC-1 upstream of breach.

Animals always active. Summertime squirrels in top of levee, and muskrat dens upward within levee with food chambers. No evidence of burrows through embankment. Saw failure in Klamath irrigation canal due to rodents. Rodents like sand. Gradall fills in holes while doing maintenance. Muskrat burrow entries are below water level. Dens above up to 18-in high, 4-ft long. Don't like rocks.

Most worried about canal at TC-1. Put gage because of high water but 700 cfs not a problem. Have had higher than 900 cfs at TC-1 and water level higher than rest of canal as at TC-1.

**Kelly Cecil – TCID Hydro Plant Supervisor (19 years with TCID, 3 years as Plant Supervisor)**

5:30PM Dave Overvold called about the Gilpin spillway because Kelly helped install the automated gate. Kelly told him to set the gate at 8.3% equivalent to about 107 cfs.

4:50AM Dave called and asked him to open gate because he didn't have the password. He called Brian Baily for password. Logged on with Dave's password and set middle gate open to 55%.

6AM Dave called again. Problem logging on and reported a problem with gate limit sensor. Sensor did not stop middle gate as it was opening and cable snapped, and gate closed. Other automatic gate worked satisfactorily.

6:30AM Dave reported another cable broken. Automatic gate opened but sensor broken which caused gate to continue opening until cable snapped, then dropped shut.

Kelly reported that TCID responded much faster to the canal breach emergency than they did during the 1996 breach.

**Walt Winder – TCID O&M Foreman since July 2005. (28 years with TCID)**

- 1/3            Noted possibility of high water based on weather forecast. Checked crane at Derby Dam and prepared trash rake.
- 1/4            Met with employees at end of day and got contact information in case they were needed. With Dave Overvold, went over gage flow correlations so he could monitor at home on computer.
- 9:30PM        Checked flow on computer. 2,500 cfs in Truckee River and 450 cfs into the canal.
- about 5AM     W.C. called to notify him of the canal breach and that Chief Henley wanted to meet him on site.
- 5:45AM        Arrived from Fallon at corner of Farm District Road and Cottonwood. Roads were bad. Met W.C. Cecil and went to breach location.. Could clearly see high water mark in canal because of snow, which was well below the crest of the embankment. Breach was about 20-ft wide and water was flowing about 1-ft deep through the breach. Gas line suspended in air across breach. Went downstream of breach to check drains.
- 6:08            Water was 3-4-ft below snow line. Took first picture from north side of canal. Later corrected time on picture for daylight savings. Drove to downstream side of breach. Command post was set up at fire station. Met with Chief Hinkle who asked how long to shut off flow? Told him about 3 hours. Told him when it was safe he would close Fernley Check.
- about 7AM     With Eugene Mawe started closing Fernley Check. Went back to command center. Talked to Highway Patrol for help moving heavy equipment from Fallon.
- about 8AM     Off loaded Cat and started temporary plug.
- about 4PM     Closed breach. Installed 36-inch pipe in canal to pass 20 – 30 cfs flow.

Based on 911 call figures time of breach was about 4AM. Not caused by overtopping because of snow line evidence.

TCID reacts case by case to rodent activity. Animals don't like rocky soil. Prefer certain areas. Time of day important. More active in morning and evening. Burrows don't penetrate more than 6 – 8-ft. Muskrat hole collapses damage canal embankment crest road. Squirrel holes smaller therefore not seen as damage to road. Bounty on burrowing animals. Beaver = \$50; gopher = \$0.50; muskrat ?? No eradication program other than bounty. Sinkholes reported in road usually due to muskrat holes. Lahontan Conservation District pays 70% of bounty and TCID the rest.

### **Ernie Schank – President of TCID Board**

President of Board from 1978 to 1982, and again from 1998 to present. Unpaid position. Family has farmed in Fallon for five generations. His family, grandfather, since 1921. He has a passion for water projects and the west.

A week before the breach TCID started preparing Derby Dam (Dave Overvold and Walt Werder) based on long range forecasts and memories of the 2005/2006 flood. Cleared trash and prepared trash removal equipment.

evening 1/4     Saw lights at Derby Dam while driving from Reno to Fallon.

9:30PM           Called Brian Baily who reported water level dropping and not much trash. Brian called Dave to raise Gilpin gates. Fell asleep on couch.

3:30AM           Woke up and checked water levels on computer. 2,900 cfs in river down.

5:15AM           Dave called and left a message.

7:30AM           Mother called and told him of breach. Drove to Fernley to meet Dave. Went to Fernley Check and saw men putting in flashboards. Complained that 2025 request to Reclamation for automatic gate operators had been turned down. Automatic operators would have saved time closing gates. Visited breach which was about 40 – 50-ft wide at the time.

Animal problems are ongoing. Ditch riders used to shoot muskrats with shotguns but no longer because of urbanization. Tried to eradicate two years ago when canal was drained. Beaver problem in the Stix reach of the canal.

Problem with the “soft dam” (fuseplug spillway) at Derby Dam after 2005/2006 flood. Walt Winder and his crew did a great job repairing.

If not for automated gates at Gilpin response time to emergency would have been much greater. Mayor of Fernley was very helpful.

### **Dave Overvold – TCID Project Manager**

Dave Overvold, TCID Project Manager participated in all the interviews but was not interviewed separately.

### **Betsy Rieke – Area Manager U.S. Bureau of Reclamation (Reclamation)**

Ongoing investigation of TCID ditch riders grievances against TCID. Minority faction of ditch riders association accuse TCID of inflating reported deliveries to Lahontan Dam instead of Pyramid Lake.. TCID earns credits from water deliveries.

Piute tribe doesn't like Newlands Project. Could sabotage.

Explosion reported accompanied by dust cloud on Saturday after breach by someone living north of Highway 50. Have name and number to contact.

Unhappy ditch riders work 25 days on 24 hours/day with 5 days off. They are classified as employees of the school district. Now working shifts.

#### **Locke Hahn – USBR, O&M, Carson City Office**

Arrived in Fernley after dark on the evening of Saturday the 5<sup>th</sup>. Sunday walked the embankment. Nothing extraordinary. Trash, algae and moss line visible low in the canal. Noticed tree stumps growing waterside which had been cut previously leaving root balls.

During inspection on Tuesday the 8<sup>th</sup> noticed gullies from the crest from rain runoff. A lot of water could be added to canal from runoff from subdivisions.

Noticed beaver or muskrat swimming. Measured hole just to east of breach. Concerned with flow in canal from Derby. Looked at side flow at Wadsworth gaging station.

1.84 inches of rain fell on January 4<sup>th</sup>.

#### **Harvey Edwards – USBR, O&N, Lahontan Area Office, Carson City**

Was notified of the canal breach at 9AM on the 5<sup>th</sup>. Arrived on site at about 12:30PM. Went to fire station about 3:30PM. Inspected the canal on the 6<sup>th</sup> and 8<sup>th</sup> and could see no obvious cause. On the 10<sup>th</sup> walked with Jeff Reiker upstream on the south side of the canal and downstream on the north side. Notice erosion gullies, small animal burrow. Identified where water line was at Anderson and Allendale Checks. No sign of overtopping erosion. Lower snow line (from photos) coincided with debris line. Higher line above snow line. Inspected for seepage around canal plugs.

#### **Ken Paar – USBR, Deputy Area Manager**

Received a call at 6AM, Saturday the 5<sup>th</sup> from Jeff Reiker notifying him of the breach. Called Central Valley office. Called Lock Hahn. Blizzard the previous day caused doors to freeze up in office making it difficult to enter. Received a call from the Commissioner at 10:30AM. Went to site with Harvey Edwards arriving about 12:30PM. Observed ongoing activities to close breach and cofferdams. Took first pictures by Reclamation. Contacted Ernie Schank and Dave Overvold. Took samples. Observed that high water mark was below top of levee.

On Sunday the 6<sup>th</sup>, gave samples to Mike McCulla. Stayed until dark. Returned to Carson City at 7PM.

**Mike McCulla – USBR, Geologist from Sacramento Regional office**

Arrived on site about 4PM on Saturday the 5<sup>th</sup>. No sign of water flowing through jointed clay/siltstone embankment foundation. Embankment appeared less homogeneous high up in the section. Mysterious triangle. Will sample. Walked downstream of breach and back up Ricci Lane. Examined various pipes penetrating the canal embankment. No opinion as to water level during flood event. Evidence of several high water marks but nothing conclusive. Most probable cause of failure muskrat holes. Could have failed at other holes.

Should check with Pat Normand, home owner at Ricci Road.

**Jeff Reiker – USBR, Hydrologic, Lahontan office, Carson City**

USGS flows increase about 80 cfs based on flow meter measurements. Disagreements between TCID and USGS. Side looking Doppler vs. Uplooking. When and how shifts? Rating of gages means 85% of readings are good and about 15% bad. Could look at local rain gages or radar to determine when rain changed to snow. Could calculate inflow downstream of Derby Dam.

Burrows and cave-ins observe and photographed on 8<sup>th</sup>. Request expert opinion of flow and water level.

**TRUCKEE CANAL FAILURE ON  
5 JANUARY 2008  
INVESTIGATIVE  
EVALUATION REPORT**

**APPENDIX B –  
INFORMATION REVIEWED**

## **TRUCKEE CANAL FAILURE ON 5 JANUARY 2008 INVESTIGATIVE EVALUATION REPORT**

### **APPENDIX B – INFORMATION REVIEWED**

#### **B1 – Preliminary Information**

The following information was provided by the U.S. Bureau of Reclamation (Reclamation) and the Truckee-Carson Irrigation District (TCID) to the URS Forensic Team (Team) for review at the time of the field visit from 12 -14 January 2008:

1. Reclamation Manual – Directives and Standards for Operation and Maintenance (RO&M)
2. Review of Operation and Maintenance Program Field Examination Guidelines
3. Lahontan Basin Area Office (LBAO) Newlands Project Review of RO&M Examination Reports 1993 - present
4. December 1996 – Exhibits K – U – Truckee Canal Failure, Flood Damage and Repairs, 1996
5. Landslide Area Near Lahontan Dam Power Plant  
December 12, 2000, USBR (MP-220) McCulla
6. Review of Operation and Maintenance (RO&M) Program – Examination of Canal Facilities, January 11, 2001, USBR – Deputy Regional Director – Lowell F. Ploss
7. Damage to Lining in the Truckee Canal from about Mile 5.9 to Mile 7.4  
September 20, 2007, USBR (MP-220) Mike McCulla
8. Transmittal of Geology Memorandum (Gilpin Wasteway and Bridge)  
September 20, 2002, USBR (MP-220) McCulla
9. The Truckee Canal Seep onto the Gay Property – Derby Wasteway Area  
November, 2002, USBR (MP-200)
10. Special Examination Report Technical Review – Truckee Canal Seep onto the Gay Property January 21, 2003, USBR (LO-100) Elizabeth Ann Rieke
11. Final Report – February 2003 Review of Operation and Maintenance – TCID Facilities, March 11, 2004, USBR (LO-100) Elizabeth Ann Rieke
12. Review of Draft Report – Truckee Canal Seep about 3.5 miles west of Hazen, NV  
May 11, 2004  
By: Bureau of Reclamation (MP-200) McCulla

13. Site Inspection of the Farm District Road Seepage Area – Truckee Canal  
December 21, 2004  
By: Bureau of Reclamation (MP-200) Sturm, McCulla
14. Truckee Canal Seep Mile-3 Site Visit Photos  
April 21, 2005  
Photos Take By: Bureau of Reclamation (MP-200) McCulla
15. Evaluation, Conclusions and Recommendations for Truckee Canal/Farm District Road Seep, December 16, 2005, USBR (MP-200) McCulla
16. 2006 Final Transmittal – Operation and Maintenance (RO&M) Report – Water Distribution System Feb 13-17, 2006, USBR – LBAO – Participants from TCID and BOR
17. Trip Report – Proposed Housing Development along the Truckee Canal Farm District Road July 2006, USBR Personnel: B.C. Deshler – LBAO, Mike Andrews – LBAO and Mike McCulla – MP-230
18. Draft Trip Report – Site Inspection of the Truckee Canal at the location of a proposed bridge, January 6, 2007
19. Truckee Canal Seep on Gay Property – Notice of Required Actions – Truckee Main Canal, April 5, 2007, USBR (LO-100) Elizabeth Ann Rieke
20. 2007 Interim Review of Operation and Maintenance Report – Water Distribution System, June 4, 2007, USBR – LBAO – Participants from TCID and BOR
21. Seepage and Lining Proposal West of Ricci Land – Truckee Main Canal, June 6, 2007, USBR (LO-100) Elizabeth Ann Rieke
22. Water Seepage Assessment – Correspondence and Reports, 2007
23. Past Examination Reports, Truckee Canal, January 9, 2008
24. Truckee Canal Inspection Reports, 2000 – 2008, USBR (MP-430)
25. 2008 Post Canal Breach Photos, January 2008
26. Drawing No. 2, U.S. Geological Survey, Reclamation Services, Truckee-Carson Project Nevada, Main Lower Truckee Canal, Cross Section of Canal, 1905, Section E-Division 2

27. Drawing No. 6186-15, Truckee Carson Project Nevada, Map of Truckee Canal Showing Location and Elevation of Structures at Pints of Diversion. Scale 1 inch = 1 mile, Department of the Interior, United States Reclamation Service, January 28, 1918.

## B2 – Supplementary Information Requested

The following matrix lists the supplementary information requested by the Team at the site investigation wrap up meeting in, Fernley, Nevada on 14 January 2008 and the persons responsible for compiling that information:

ITEM	RESPONSIBLE
1. Map of Canal Including: a. Breach Location i. Structure Locations and Types ii. Historic Breach Locations and Dates iii. Areas of Special Interest for Monitoring	Dave Mello/Terri Reaves
2. Photographs (Electronic Format)	Jillian Baber
3. Flow records for the canal and a best estimate of a time history of flow water levels around the time of the breach.	Jeff Rieker/Dave Overvold
4. Site/breach topography and topography at the gap in the uphill (right) bank.	Dave Mello/Terri Reaves
5. Water line elevations at the breach a. Rating curve showing elevation versus flow rate b. Elevations at normal checked-up condition	Dave Mello/Terri Reaves
6. Geologic map of area	Mike McCulla
7. LiDAR image of breach face	Dave Mello/Terri Reaves
8. Laboratory test results	Mike McCulla/Rick Davis
9. Reports of 1996 Failure	Locke Hahne, Ken Lally
10. Reports of Other Failures if Available	Locke Hahne, Ken Lally
11. Results of January 2008 Inspections	Sheila Masters
<b>Additional Data to Collect/Investigations to Perform</b>	
1. Map and sample the upstream face of breach similar to what was done for the downstream face.	Mike McCulla/Dave Mello/Terri Reaves
2. Map and sample the remainder of the downstream face not previously completed.	Mike McCulla/Dave Mello/Terri Reaves
3. Density tests in the embankment and foundation materials.	Mike McCulla/Rick Davis

ITEM	RESPONSIBLE
4. Explore animal hole approximately 300 feet downstream of the breach a. Survey upstream and downstream locations b. Attempt to fill burrow(s) and excavate to reveal extent of burrow(s)	Russ Troutman
5. Hole erosion tests: a. Embankment (reconstituted) b. Foundation claystone layers (undisturbed samples)	Mike McCulla/Rick Davis

### **B3     Supplementary Information Received**

The following information was provided by Reclamation to the Team for review subsequent to the field visit from 12 -14 January 2008:

1.     Truckee Canal Breach, Station 714+00, Geologic Investigations, January 2008, USBR (MP-230)
2.     Truckee Canal Breach, Station 716+50, Muskrat Burrow Investigations, January 2008, USBR (MP-230)
3.     Initial Hydrologic Analysis of the Truckee Canal Breach, February 4, 2008, USBR (LO-900)
4.     Draft - Truckee Main Canal – 2008 Special Embankment Inspection, USBR
5.     Truckee Canal, Derby Dam to Lahontan Reservoir, Hydraulic Sections, January 2008, USBR
6.     Photogrammetric Horizontal Alignment, Photogrammetric Sections and Hydraulic Sections, 2008, USBR

# **TRUCKEE CANAL EMBANKMENT FORENSIC EVALUATION REPORT**

## **APPENDIX C – PHOTOGRAPHS**

## PHOTOGRAPHS

- Photo 1. First photograph taken at point of failure. View looking south across canal. Note high water mark in canal during high flow event as evidenced by fresh snow. Photo by Walt Winder, 6:08 a.m., 01-05-2008.
- Photo 2. Canal looking downstream (east). Breach at left. Photo by Walt Winder approximately 6:15 a.m., 01-05-2008.
- Photo 3. Canal breach (about Sta. 714+00) looking north. Water flowing towards Fernley. Water normally flows left to right. Photo by Kenneth Parr, 1:04 p.m., 01-05-2008.
- Photo 4. Drained canal clearly showing high water level during high flow event as evidenced by unmelted fresh snow which fell during early morning hours of 01-05-2008. Photo by Ernie Schank.
- Photo 5. Downstream view of canal breach. Dashed black line is approximate contact between canal embankment and in-place lakebed deposits (Ql). Center-left is an abandoned Sierra Pacific Power gas pipeline. Photo by Kenneth Parr, 2:07 p.m., 01-05-2008.
- Photo 6. View towards Fernley from top of the breach plug. Photo by M. McCulla, 01-06-2008.
- Photo 7. View of downstream face of breach showing approximate contact between embankment and in-place Quaternary lakebed sediment (Ql). Photo by M. McCulla, 01-06-2008.
- Photo 8. Test located in the invert of breach. Test pit was in lakebed sediments. Photo by M. McCulla, 01-13-2008.
- Photo 9. Test pit about 120 feet upstream from breach. Test pit exposed lakebed sediments overlying alluvial fan deposits. Photo by M. McCulla, 01-13-2008.
- Photo 10. Test pit showing contact between alluvial fan deposits and overlying lakebed sediments. Photo by M. McCulla, 01-13-2008.
- Photo 11. Left canal embankment looking downstream, showing relative locations of collapse feature (right), muskrat burrows (left), and breach (top center). Photo by M. McCulla, 01-13-2008.
- Photo 12. Canal bank looking north, showing relative position of muskrat burrows and collapse feature about 240 feet downstream from breach. Photo by M. McCulla, 01-14-2008.
- Photo 13. Three muskrat burrows across from collapse feature in left canal bank. Note high waterline in canal bank. Photo by M. McCulla, 01-14-2008.
- Photo 14. Landside, left canal bank, about 240 feet downstream from canal breach. Collapse feature associated with downhill sediment transport. Three muskrat burrows on the canal side of the embankment near high water line. Photo by M. McCulla, 01-13-2008.
- Photo 15. View from north side of canal looking towards collapse feature. Workers standing on sediment transported downhill from the collapse feature. Photo by M. McCulla, 01-13-2008.
- Photo 16. Small delta of sediment transported downhill from collapse feature. Photo by M. McCulla, 01-13-2008.
- Photo 17. View of hollow-stem stratathane injection pipes. Worker is near location of the muskrat burrows on the canal side, and view is from area near collapse feature. Photo by M. McCulla, 01-22-2008.
- Photo 18. View of main muskrat burrows entering from canal. Note one of several cracks parallel embankment. Photo by M. McCulla, 01-23-2008.
- Photo 19. Close up of the main muskrat burrow. "T" structure shown is about nine feet in from canal. Photo by M. McCulla, 01-13-2008.
- Photo 20. View towards canal showing muskrat burrows and cracks between canal and abandoned gas pipeline, 23 feet from canal. Photo by M. McCulla, 01-23-2008.
- Photo 21. Downstream view of canal (right) and stratathane casts of muskrat burrows, cracks, and other voids painted orange. Photo by M. McCulla, 01-24-2008.



Photo 1. First photograph taken at point of failure. View looking south across canal. Note high water mark in canal during high flow event as evidenced by fresh snow. Photo by Walt Winder, 6:08 a.m., 01-05-2008.



Photo 2. Canal looking downstream (east). Breach at left. Photo by Walt Winder approximately 6:15 a.m., 01-05-2008.



Photo 3. Canal breach (about Sta. 714+00) looking north. Water flowing towards Fernley. Water normally flows left to right. Photo by Kenneth Parr, 1:04 p.m., 01-05-2008.



Photo 4. Drained canal clearly showing high water level during high flow event as evidenced by unmelted fresh snow which fell during early morning hours of 01-05-2008. Photo by Ernie Schank.



Photo 5. Downstream view of canal breach. Dashed black line is approximate contact between canal embankment and in-place lakebed deposits (QI). Center-left is an abandoned Sierra Pacific Power gas pipeline. Photo by Kenneth Parr, 2:07 p.m., 01-05-2008.



Photo 6. View towards Fernley from top of the breach plug. Photo by M. McCulla, 01-06-2008.

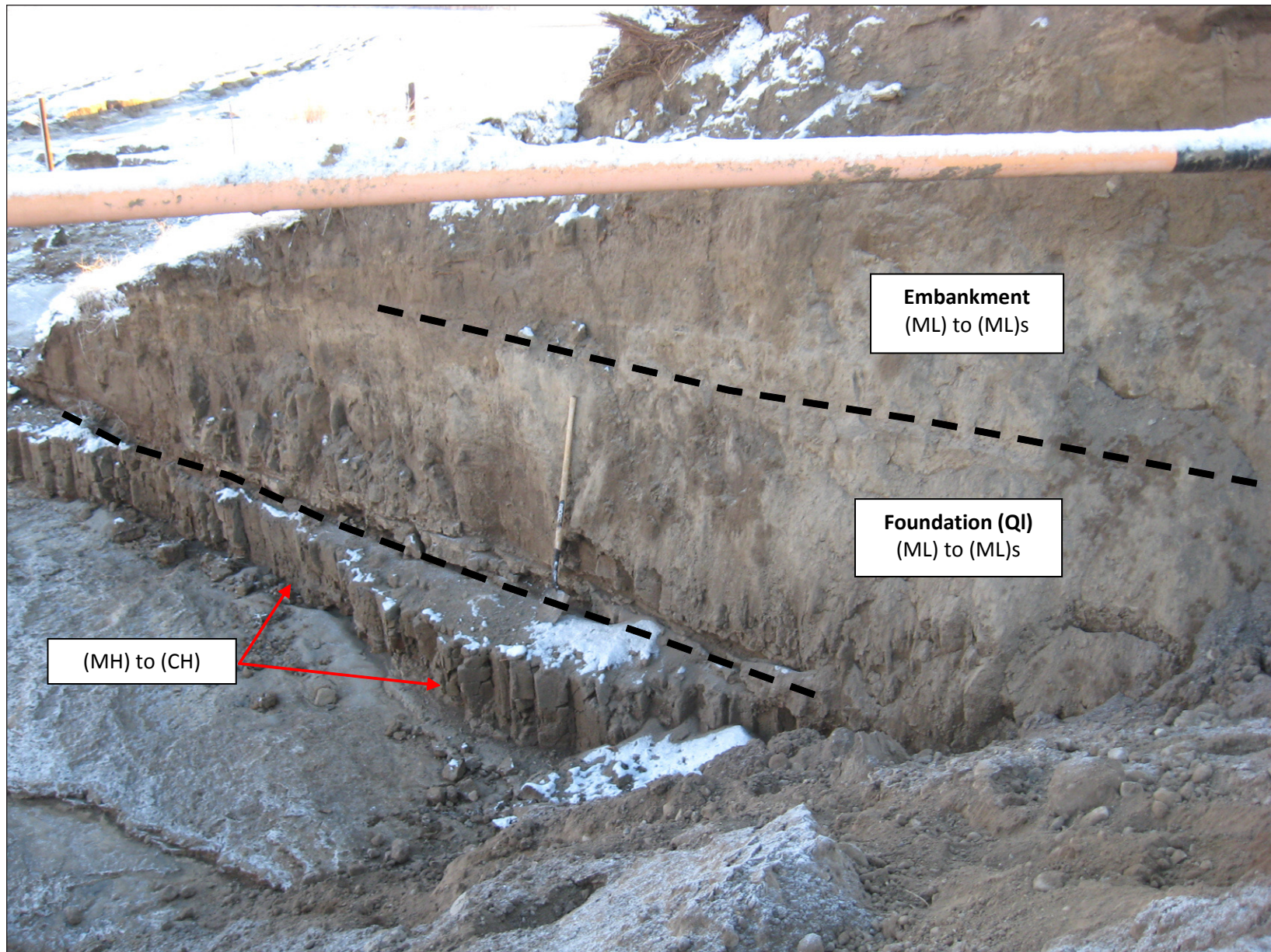


Photo 7. View of downstream face of breach showing approximate contact between embankment and in-place Quaternary lakebed sediment (QI). Photo by M. McCulla, 01-06-2008.



Photo 8. Test located in the invert of breach. Test pit was in lakebed sediments. Photo by M. McCulla, 01-13-2008.



Photo 9. Test pit about 120 feet upstream from breach. Test pit exposed lakebed sediments overlying alluvial fan deposits. Photo by M. McCulla, 01-13-2008.



Photo 10. Test pit showing contact between alluvial fan deposits and overlying lakebed sediments. Photo by M. McCulla, 01-13-2008.



Photo 11. Left canal embankment looking downstream, showing relative locations of collapse feature (right), muskrat burrows (left), and breach (top center). Photo by M. McCulla, 01-13-2008.



Photo 12. Canal bank looking north, showing relative position of muskrat burrows and collapse feature about 240 feet downstream from breach. Photo by M. McCulla, 01-14-2008.



Photo 13. Three muskrat burrows across from collapse feature in left canal bank. Note high waterline in canal bank. Photo by M. McCulla, 01-14-2008.



Photo 14. Landside, left canal bank, about 240 feet downstream from canal breach. Collapse feature associated with downhill sediment transport. Three muskrat burrows on the canal side of the embankment near high water line. Photo by M. McCulla, 01-13-2008.



Photo 15. View from north side of canal looking towards collapse feature. Workers standing on sediment transported downhill from the collapse feature. Photo by M. McCulla, 01-13-2008.



Photo 16. Small delta of sediment transported downhill from collapse feature. Photo by M. McCulla, 01-13-2008.

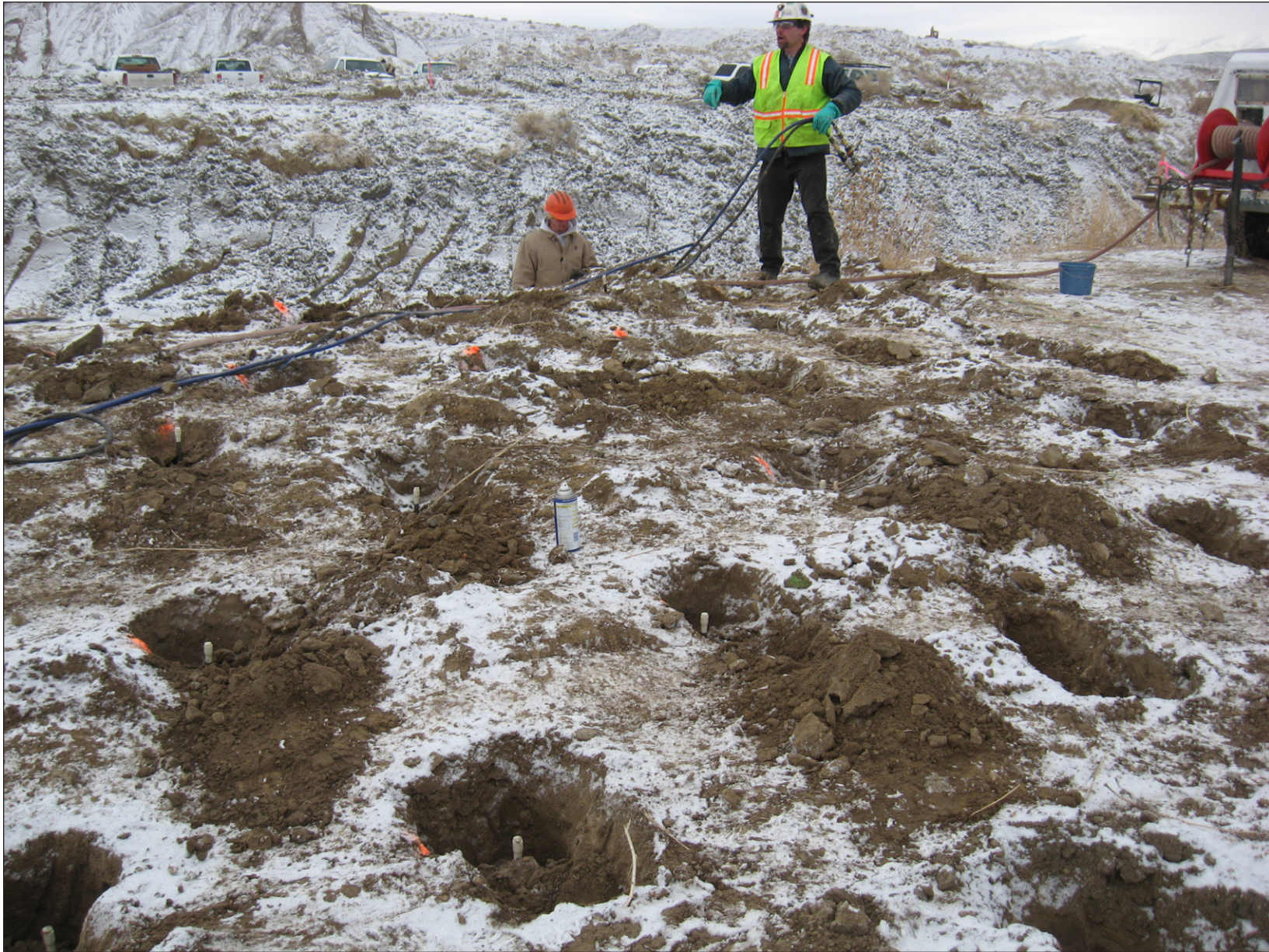


Photo 17. View of hollow-stem stratathane injection pipes. Worker is near location of the muskrat burrows on the canal side, and view is from area near collapse feature. Photo by M. McCulla, 01-22-2008.

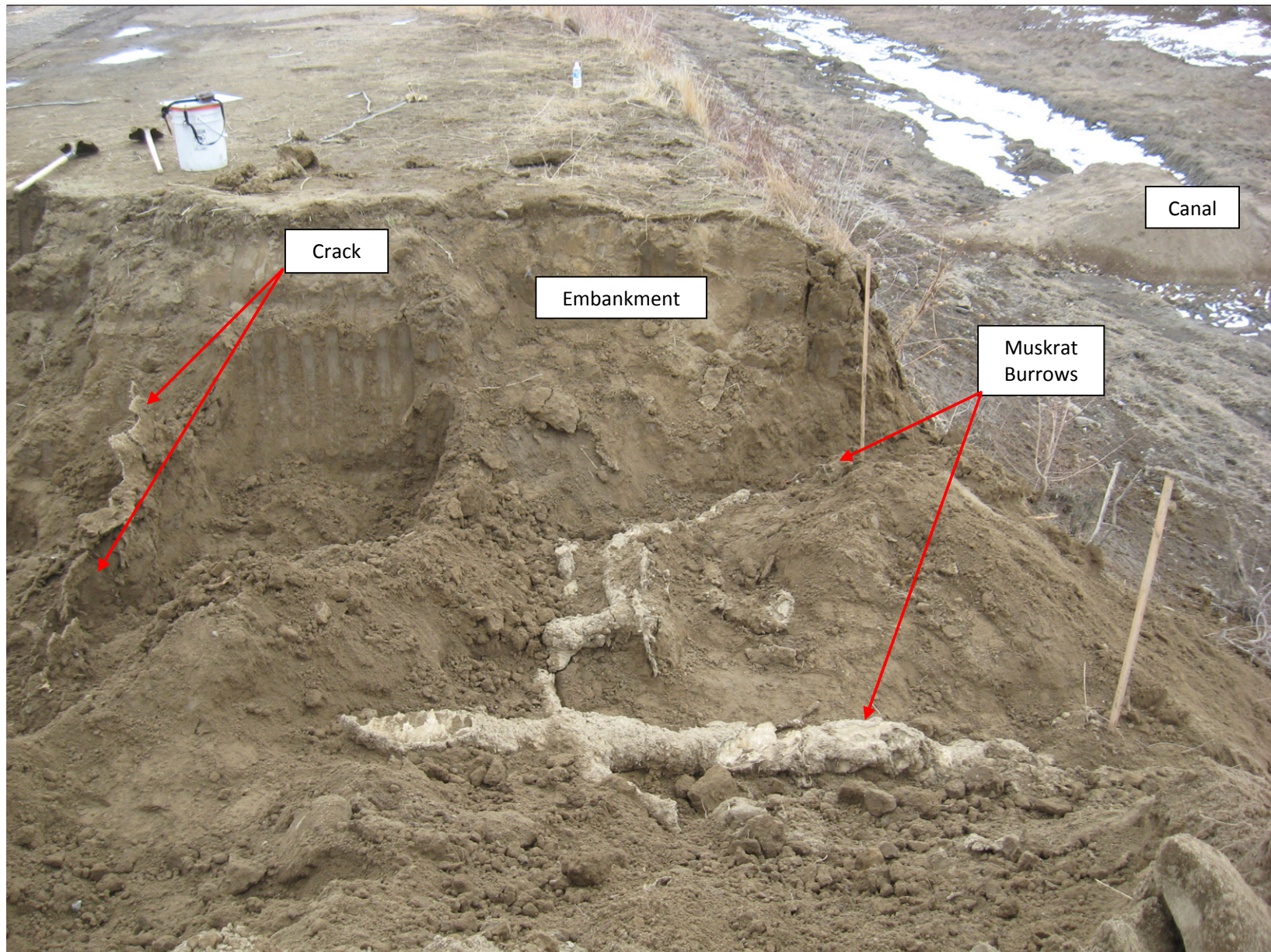


Photo 18. View of main muskrat burrows entering from canal. Note one of several cracks parallel embankment. Photo by M. McCulla, 01-23-2008.



Photo 19. Close up of the main muskrat burrow. "T" structure shown is about nine feet in from canal. Photo by M. McCulla, 01-13-2008.

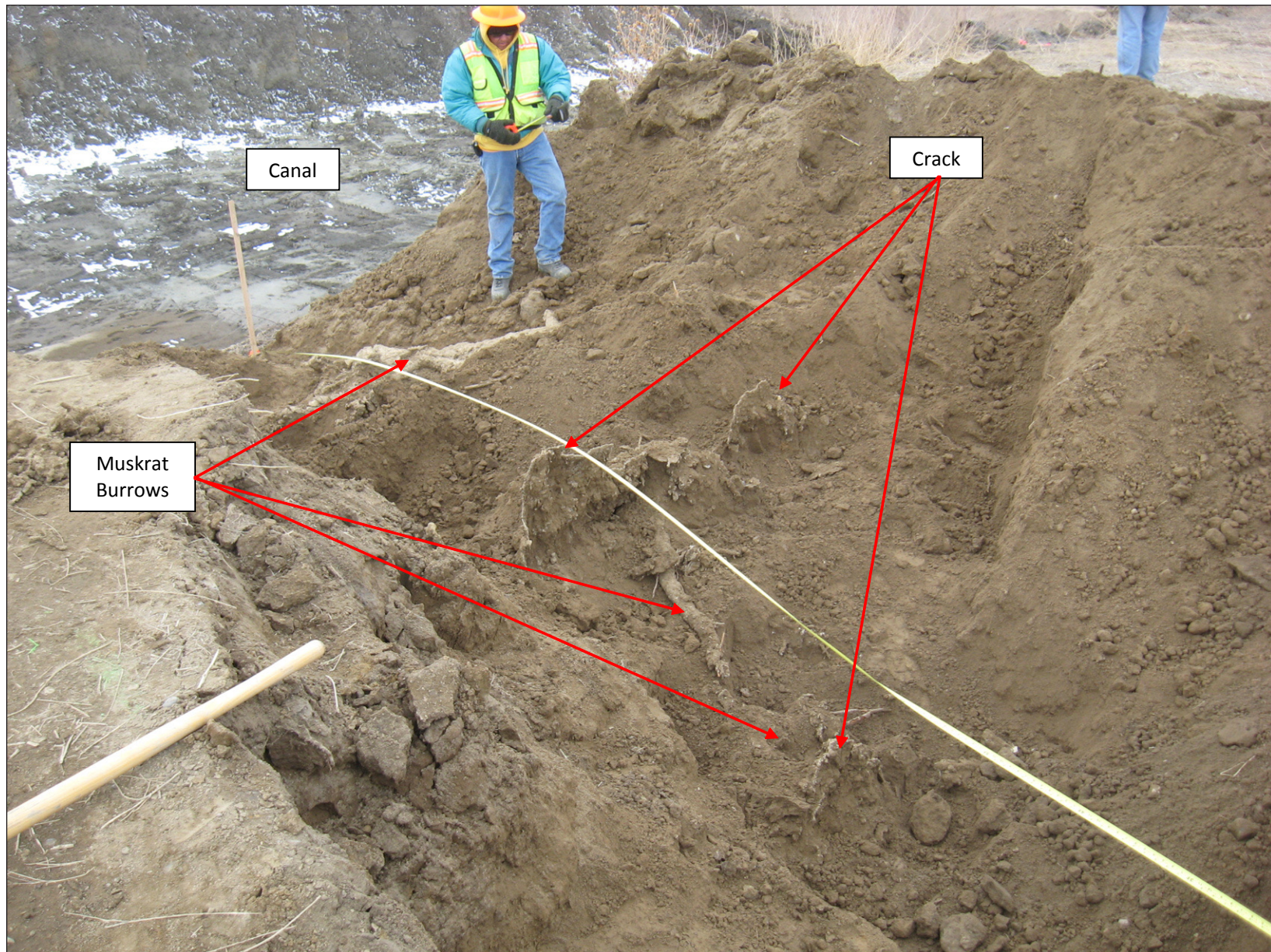


Photo 20. View towards canal showing muskrat burrows and cracks between canal and abandoned gas pipeline, 23 feet from canal.  
Photo by M. McCulla, 01-23-2008.

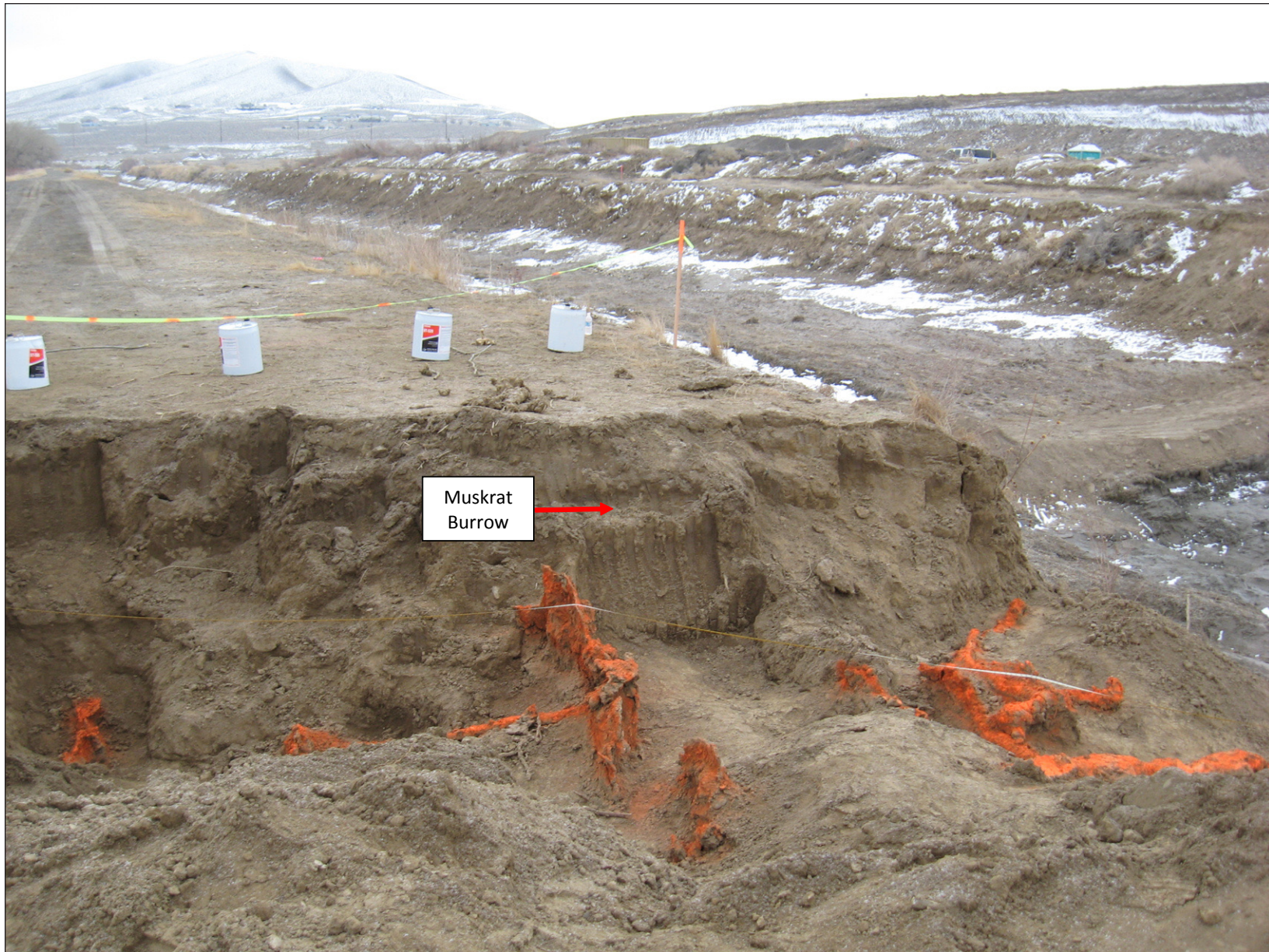


Photo 21. Downstream view of canal (right) and stratathane casts of muskrat burrows, cracks, and other voids painted orange. Photo by M. McCulla, 01-24-2008.